Conodonts from the Ordovician–Silurian Boundary Stratotype, Dob's Linn, Scotland

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Synopsis

About one hundred poorly preserved conodonts have been collected from surfaces of shale from seven graptolite zones of the Dob's Linn boundary stratotype section, mainly from the *D. anceps* Zone. Attempts to recover conodonts by dissolving siltstones and cherts from the section were unsuccessful. When preserved, the conodont phosphatic material provides Colour Alteration Index values of CAI 5–7, indicating burial temperatures in excess of 300°C. The sparse, low diversity faunas assist in correlating conodont and graptolite zones. *Amorphognathus* sp. and *Scabbardella* sp. cf. *S. altipes* were found in the *G. persculptus* Zone, suggesting that the conodont turnover must lie at least high within this zone. Lowest Silurian strata yielded rare, undiagnostic coniform taxa and an element referred tentatively to *Oulodus*? *kentuckyensis*. The results encourage further efforts in retrieving conodonts from graptolitic shale sequences, but the precise correlation of the conodont turnover with respect to the defined base of the Silurian remains in question.

Introduction

The Ordovician–Silurian boundary was finally designated in 1985 at 1·6 m above the base of the Birkhill Shale in the Linn Branch section of Dob's Linn, southern Scotland, at the base of the *Parakidograptus acuminatus* Zone (Williams 1983 and this volume; Cocks 1985). Detailed work on the rich graptolite faunas has been carried out by a number of previous researchers, especially Lapworth, Elles & Wood, Toghill and Williams (see Williams 1983, this volume). The section, however, has yielded no other biostratigraphically useful fossils in abundance; there are rare inarticulate brachiopods (Williams & Lockley 1983) and a species of a blind dalmanitid trilobite. Lamont & Lindström (1957) reported conodonts from cherts in the Southern Uplands of Scotland, including Dob's Linn, but only gave identifications and details of the Arenig and Llandeilo faunas.

One critical problem in the debate concerning the definition of the Ordovician–Silurian boundary and subsequent selection of a stratotype was that few candidate sections contained both graptolites and conodonts. At the level of the *G. persculptus* and *P. acuminatus* Zones (Fig. 1) in particular, there are difficulties in correlating the graptolite and conodont zones and the two respective extinction events (e.g. Barnes & Bergström, this volume). It is, therefore, both encouraging and important to report in this paper the discovery of conodonts at several levels in the Dob's Linn boundary stratotype section.

While scanning shale surfaces under the microscope during the investigation of graptolites, Williams observed a number of microfossils which have since been identified by Barnes. Further collections were made by Williams in 1985; this time, in addition to the scanning of shale surfaces, samples of shales, siltstones and cherts were processed through a variety of standard chemical rock digestion techniques employed for conodonts (e.g. acetic and hydrofluoric acids; bleach). The latter results were disappointing in that most lithologies appeared to be barren of conodonts, although this may have been due to inadequate preservation (see below). The remaining new collections revealed many additional conodont horizons, but yielded few diagnostic elements from new stratigraphical levels. This project however demonstrates that conodonts are present, and moderately abundant at some horizons, in graptolitic shales deposited in a deep oceanic environment which has been interpreted as an accretionary prism (McKerrow *et al.* 1979; see other recent interpretations by Needham & Knipe 1986 and

Bull. Br. Mus. nat. Hist. (Geol) **43**: 31–39 Issued 28 April 1988

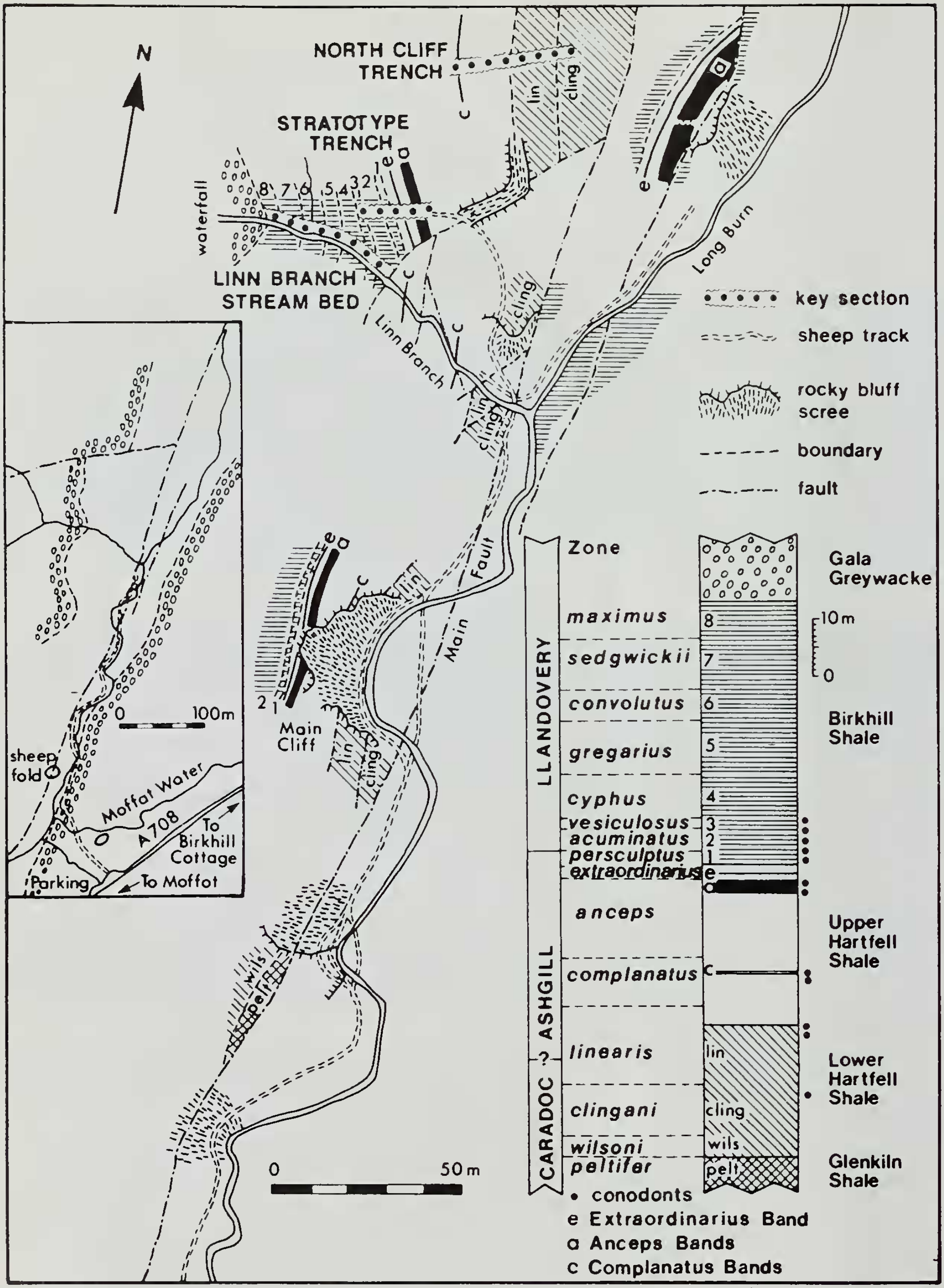


Fig. 1 Simplified geological map and stratigraphical section of Dob's Linn, showing position of conodont localities and horizons (after Williams 1980).

Murphy & Hutton 1986). Careful microscopical examination of similar shales in other sequences should reveal many new conodont faunas and assist integration of graptolite and conodont biostratigraphic zonation schemes.

Results

Following the discovery of the microfossils, re-examination of earlier material, together with the new shale collections, has involved the study of several hundred surfaces for conodonts. Conodonts and rare scolecodonts are present. The conodonts always occur as isolated elements; no fused clusters or natural assemblages were discovered. The elements are poorly preserved, typically being fractured by tectonic stretching and commonly with only part of the phosphatic skeletal material preserved. This may, in part, explain the difficulty in obtaining identifiable conodonts from dissolved samples. For some, only an external mould remains, but latex casts have been successfully made which permit specific identifications (e.g. Pl. 1, fig. 10; Pl. 2, fig. 12). The conodonts provide Colour Alteration Index values of CAI 5–7. This is in agreement with the general high thermal values reported elsewhere in the Southern Uplands of Scotland by Bergström (1980), indicating burial temperatures exceeding 300°C.

About one hundred conodont elements have been recognized, the majority of which are identifiable only to generic level. The diversity of the fauna is low, but zonal species are present. Nearly all the conodonts come from Ordovician strata, in particular the *D. anceps* Zone; unfortunately, conodonts are especially rare near the Ordovician–Silurian boundary.

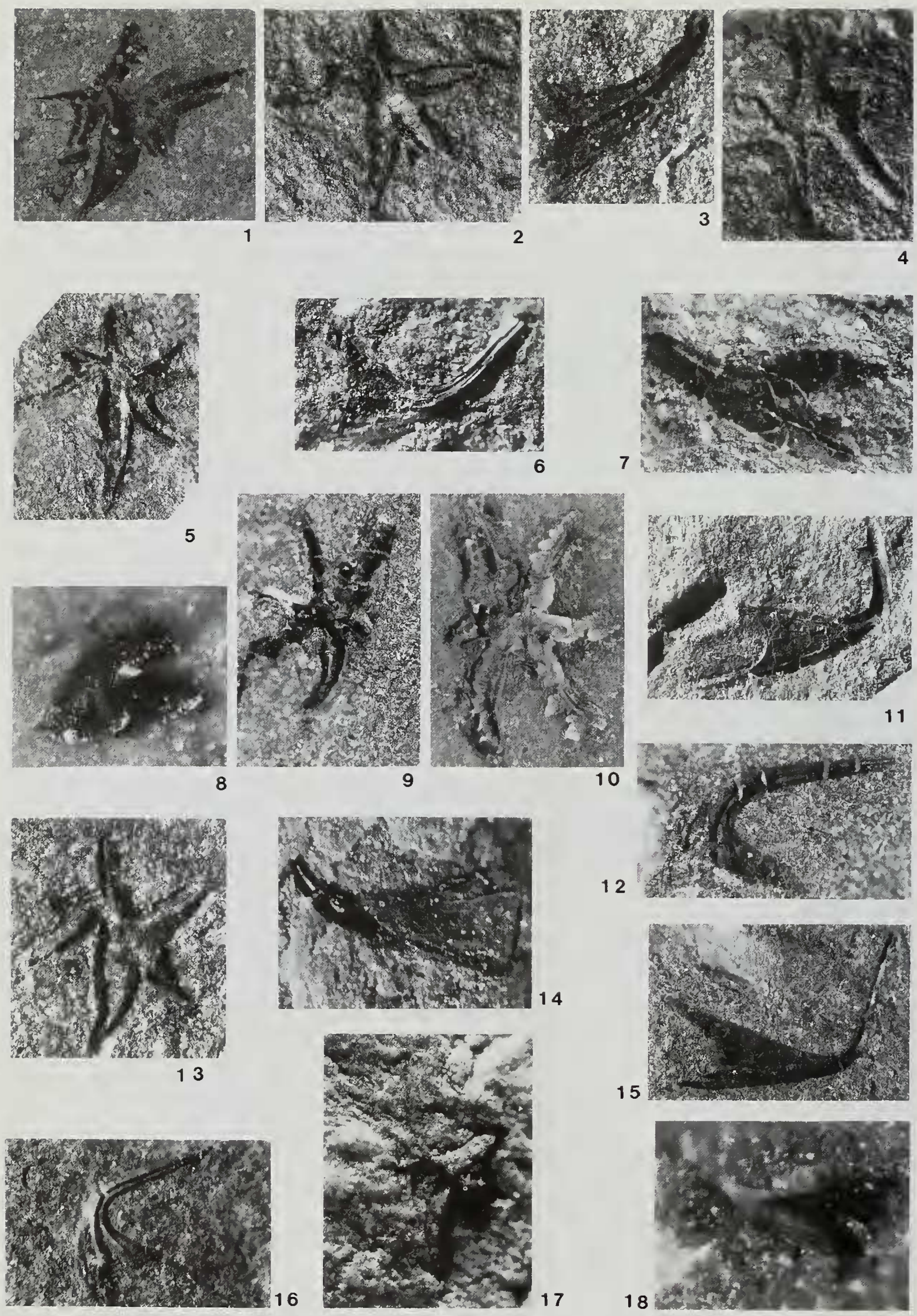
Hartfell Shale conodonts

Most of the conodonts from the Dob's Linn section come from the Hartfell Shale. They were recovered at various levels within the *Dicranograptus clingani*, *Pleurograptus linearis*, *Dicellograptus complanatus* and *D. anceps* Zones, but principally from the latter zone. Details of stratigraphy, together with a revision of the graptolite faunas from the *D. clingani*, *P. linearis*, and *D. anceps* Zones, have been published by Williams (1982*a*, *b*). Conodonts from the *D. clingani* Zone were not identifiable; those from the *P. linearis* Zone included two specimens of *Amorphognathus superbus* (Rhodes) from 1·1–1·2 m and 0·3–0·45 m below the top of the Lower Hartfell Shale, several specimens of *Amorphognathus* sp. and a specimen of *Walliserodus* unidentifiable to species level.

The precise level at which *A. superbus* evolved into *A. ordovicicus* (i.e. base of the *A. ordovicicus* Zone) in terms of graptolite zones remains to be established. This zonal boundary appears to lie within the upper Pusgillian Stage or lower Cautleyan Stage (Bergström 1971, 1983; Orchard 1890; Bergström & Orchard 1985), although Savage & Bassett (1985) tentatively suggest a late Caradoc age. In North America, this boundary occurs in the lower Maysvillian Stage (Sweet & Bergström 1971). The *D. clingani–P. linearis* zonal boundary is approximately equivalent to, or slightly predates, the base of the earliest Ashgill Pusgillian Stage (Williams & Bruton 1983). The samples yielding *A. superbus* are from the top of the Lower Hartfell Shale (mid *P. linearis* Zone; Williams 1982*a*: fig. 3) which probably falls within the Pusgillian Stage.

A single identifiable conodont was recovered from the *D. complanatus* Zone of the Upper Hartfell Shale, namely *Amorphognathus ordovicicus* Branson & Mehl from the lower Complanatus Band. At Myoch Bay in the Girvan area, southern Scotland, the *D. complanatus* Zone of the Upper Whitehouse Group also yields shelly fossils of Pusgillian age (Ingham 1978; Harper 1979). Conodonts from these strata (Sweet & Bergström 1976: 135–136; Bergström & Orchard 1980) do not allow a zonal assignment. It must be emphasized that the material at hand comprises only a single, poorly preserved amorphognathodontiform element; this limited evidence suggests that the *A. ordovicicus* Zone boundary lies within the Pusgillian rather than the Cautleyan.

The *D. anceps* Zone is recognized in the Upper Hartfell Shale by a series of thin black shales assigned to Anceps Bands A–E (e.g. Williams 1982*b*). These contain the most abundant conodont fauna from the Dob's Linn section. No significant difference was observed in the conodont fauna of the various bands except in terms of relative abundance. Band A yielded rare speci-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mens assignable to only two species: *Amorphognathus ordovicicus* and *Protopanderodus liripipus* Kennedy, Barnes & Uyeno. Band B produced conodonts referred to *A.* sp. cf. *A. ordovicicus*, *Scabbardella altipes* (Henningsmoen) and an oistodontiform element that probably belonged to *Hamarodus europaeus* (Serpagli). Band C contained only *P. liripipus*, and Band D yielded *A.* sp. cf. *A. ordovicicus* and *S. altipes*; both had only rare fragmentary conodonts. Band E contained slightly more specimens including *Amorphognathus* sp., *P. liripipus* and *S. altipes*. The *D. anceps* Zone therefore yields conodonts belonging to the *A. ordovicicus* Zone. Orchard (1980) recovered *H. europaeus* from only Rawthyan and Hirnantian strata although the range of this species has now been extended into the Cautleyan by Barnes & Bergström (this volume).

No conodonts were recovered from the 1-cm black shale *Extraordinarius* Band of the top Upper Hartfell Shale, which yields *C.*? *extraordinarius* Zone graptolites of probable mid-Hirnantian age (Williams 1983).

Birkhill Shale conodonts

The Birkhill Shale includes the upper part of the top Ordovician *G. persculptus* Zone, the basal Silurian *Parakidograptus acuminatus* Zone and subsequent Llandovery graptolite zones (Toghill 1968; Williams 1983). The lower few metres of the Birkhill Shale is the critical interval from which turnover conodonts need to be recovered, but unfortunately no especially diagnostic taxa were found.

In strata of the *G. persculptus* Zone, the few specimens observed were all coniform except for one slightly crushed and distorted specimen of *Amorphognathus* sp. from 0·12–0·2 m above the base of the Birkhill Shale. The coniform taxa include *Dapsilodus obliquicostatus* (Branson & Mehl) and *Scabbardella* sp. cf. *S. altipes*. The latter occurs at 0·95 m above the base of the Birkhill Shale. Neither *Amorphognathus* nor *Scabbardella* are known with certainty from Silurian strata. This limited evidence, based on rare, poorly preserved specimens, suggests that most of the *G. persculptus* Zone may lie below the main Ordovician–Silurian conodont turnover (see discussion by Barnes & Bergström, this volume).

The *P. acuminatus* Zone, beginning at 1·6 m above the base of the Birkhill Shale, and the overlying *Cystograptus vesiculosus* Zone contained a few conodonts assigned to *Dapsilodus obliquicostatus* and *Decoriconus* sp. In addition a single, small, poorly preserved ligonodiniform element was found at 1·75 m above the base of the Birkhill Shale. The form of the lateral

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PLATE 1 Conodonts from the Lower and Upper Hartfell Shale, Dob's Linn, Scotland.

Figs 1, 2 *Amorphognathus superbus* (Rhodes) × 35. 1, dextral blade element, upper view. HM Y155. 1·1 m below top of Lower Hartfell Shale, *P. linearis* Zone. North Cliff. 2, dextral blade element, upper view of mould. HM Y157. 0·3–0·45 m below top of Lower Hartfell Shale, North Cliff.

Fig. 3 *Walliserodus* sp. × 70. Lateral view. HM Y201. Top of Lower Hartfell Shale, North Cliff.

Figs 4, 5, 13 *Amorphognathus ordovicicus* Branson & Mehl. × 35. Upper Hartfell Shale. 4, sinistral blade element, upper view of mould. HM Y159. Lower *Complanatus* Band. 5, dextral blade element, upper view of mould. HM Y107. *Anceps* Band A. Long Burn. 13, dextral blade element, upper view of mould. HM Y129. *Anceps* Band D. Main Cliff.

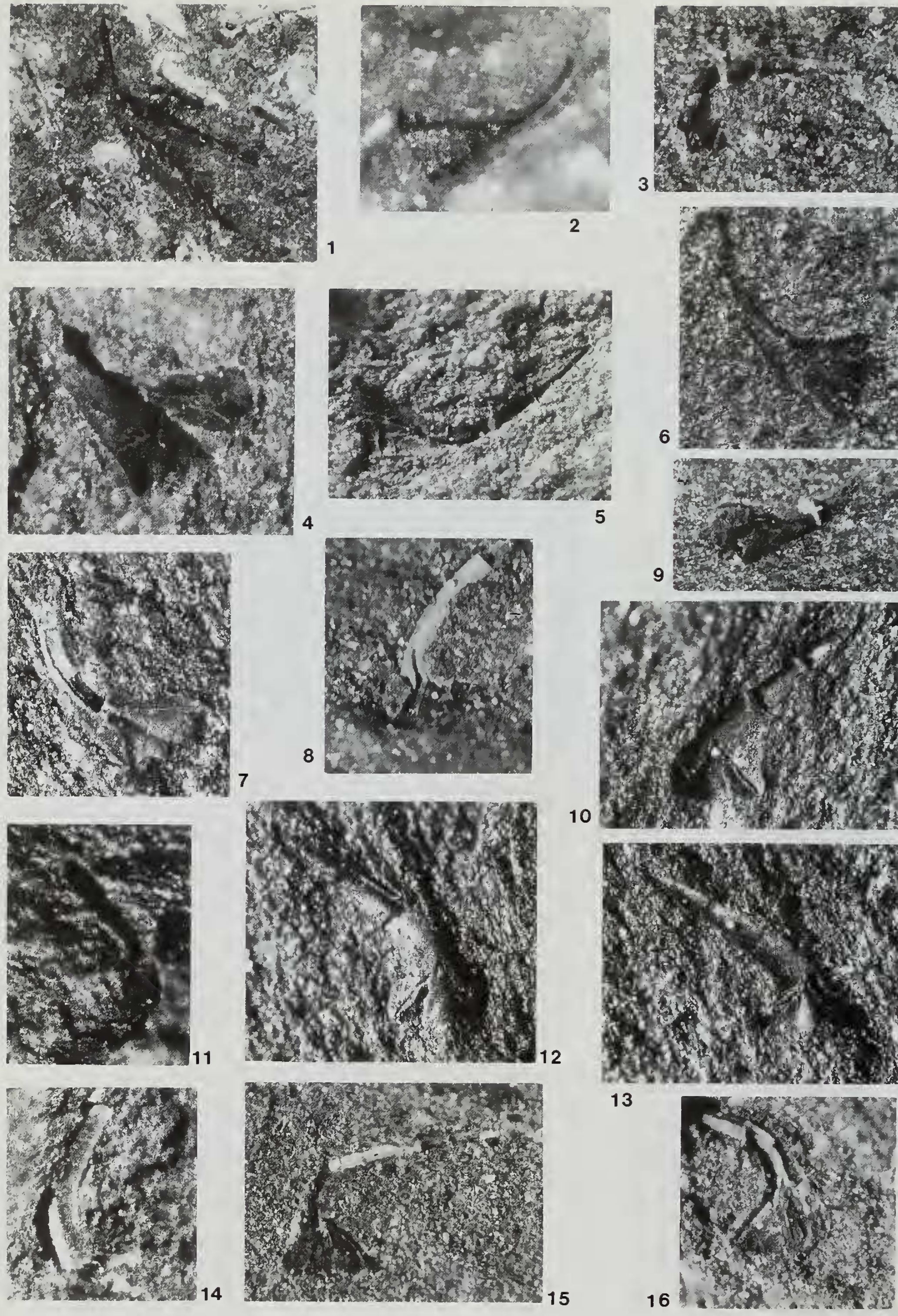
Figs 6, 12, 16 *Protopanderodus liripipus* Kennedy, Barnes & Uyeno. × 55. Upper Hartfell Shale. 6, scandodontiform element. HM Y109a. *Anceps* Band A, Long Burn. 12, symmetrical element. HM Y121. *Anceps* Band C. Main Cliff. 16, scolopodontiform element. HM Y135. *Anceps* Band E. Linn Branch.

Figs 7, 11, 14, 15, 18 *Scabbardella altipes* Henningsmoen. Lateral views. × 55. Upper Hartfell Shale. 7, ?acodontiform element. HM Y203. *Anceps* Band B. Linn Branch. 11, distacodontiform element. HM Y112. *Anceps* Band B. Main Cliff. 14, acodontiform element. HM Y202. *Anceps* Band D. Linn Branch. 15, distacodontiform element. HM Y126. *Anceps* Band D. Long Burn. 18, distacodontiform element. HM Y204. 40 cm above *Anceps* Band E, Linn Branch.

Fig. 8 *Hamerodus europaeus* (Serpagli). × 55. Oistodontiform element. HM Y205. *Anceps* Band B. Linn Branch.

Figs 9, 10 *Amorphognathus* sp. cf. *A. ordovicicus* Branson & Mehl. × 35. 9, dextral blade. Upper view of mould. HM Y114b. *Anceps* Band B. Main Cliff. 10, latex cast of HM Y114b (Fig. 9).

Fig. 17 *Amorphognathus* sp. × 35. Dextral blade element, upper view of mould. HM Y136. *Anceps* Band E. Linn Branch.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process extends into the shale but its shape is revealed by a latex cast. The element is assigned tentatively to *Oulodus*? *kentuckyensis* (Branson & Mehl). The latter species is known only from Silurian strata elsewhere (e.g. Anticosti Island, McCracken & Barnes 1981).

Summary

About 100 conodont elements have been observed on shale surfaces from the Dob's Linn boundary stratotype section. Most are from black shales, but occasional specimens also occur within paler grey shales and siltstones. The elements are poorly preserved, fractured and commonly occur as moulds; the Colour Alteration Index values are in the range of CAI 5–7 indicating burial temperatures exceeding 300°C. Identification of most elements can be made only to generic level; a selection of the better specimens are here illustrated (Figs 2, 3) but the photography for many proved difficult and not all details of micromorphology could be reproduced. The diversity of the faunas is low, typically 3–5 species per graptolite zone interval. This may be expected in the deep oceanic environment of the Hartfell Shale and Birkhill Shale, but is probably also related to the limited material discovered. Siltstone, shale and chert samples were also processed chemically but yielded no identifiable conodonts. Although the sparse fauna and poor preservation must be taken into account, the following biostratigraphic conclusions may be drawn from this study.

1. *Amorphognathus superbus* is present in the *Pleurograptus linearis* Zone near the top of the Lower Hartfell Shale (based only on amorphognathodontiform, not holodontiform elements). *Amorphognathus ordovicicus* occurs in the *Dicellograptus complanatus* Zone of the Upper Hartfell Shale. This suggests that the *A. superbus*–*A. ordovicicus* zonal boundary is not far removed from that of the *P. linearis* and *D. complanatus* Zones and lies within the Pusgillian Stage.

2. Most of the conodonts come from the *Dicellograptus anceps* Zone; all the *Anceps* Bands A–E of the Upper Hartfell Shale yielded specimens, which are indicative of the *A. ordovicicus* Zone. Conodonts also occur at several grey, silty, non-graptolitic horizons during this interval.

3. No conodonts were recovered from the 1-cm black shale of the *Climacograptus*? *extraordinarius* Zone.

4. The lower 1·6 m of the Birkhill Shale, belonging to the *Glyptograptus persculptus* Zone, contained two poor specimens of *Amorphognathus* sp. and *Scabbardella* sp. cf. *S. altipes*, known only from Ordovician strata. This suggests that the major conodont turnover (Barnes & Bergström, this volume) occurred at a level equivalent to at least high in the *G. persculptus* Zone.

PLATE 2 Conodonts from the Birkhill Shale, Dob's Linn, Scotland. Figs 1–16 arranged in order of stratigraphical occurrence of specimens. *G. persculptus* Zone (Figs 1–9); *P. acuminatus* Zone (Figs 10–14); *C. vesiculosus* Zone (Figs 15, 16).

Fig. 1 *Amorphognathus* sp. × 35. Upper view, distorted specimen. HM Y142. 0·12–0·2 m above base of Birkhill Shale.

Figs 2, 3, 5, 9 *Dapsilodus* sp. Lateral views. 2, HM Y206. × 90. 0·55 m above base of Birkhill Shale. 3, HM Y207. × 55. 0·95 m above base of Birkhill Shale. 5, HM Y208. × 80. 0·95 m above base of Birkhill Shale. 9, HM Y209. × 55. 1·5 m above base of Birkhill Shale.

Figs 4, 6 *Scabbardella altipes* Henningsmoen. Lateral views. × 55. 4, HM Y210. 0·95 m above base of Birkhill Shale. 6, HM Y211. 0·95 m above base of Birkhill Shale.

Figs 7, 15, 16 *Dapsilodus obliquicostatus* (Branson & Mehl). Lateral views. 7, HM Y213. × 70. 1 m above base of Birkhill Shale. 15, HM Y214. × 55. 5 m above base of Birkhill Shale. 16, HM Y215. × 55. 5·5 m above base of Birkhill Shale.

Fig. 8 *Drepanoistodus* sp. × 70. Lateral view. Drepanodontiform element. HM Y212. 1 m above base of Birkhill Shale.

Figs 10, 12, 13 *Decoriconus* sp. × 55. Lateral views. 10, HM Y216. 1·75 m above base of Birkhill Shale. 12, HM Y217. 1·75 m above base of Birkhill Shale. 13, latex cast of HM Y217 (Fig. 12).

Figs 11, 14 cf. *Oulodus*? *kentuckyensis* (Branson & Branson). × 105. Lateral views. 11, ligonodiniform element. HM Y218. 1·75 m above base of Birkhill Shale. 14, latex cast of HM Y218 (Fig. 11).

5. Silurian conodonts from the *Parakidograptus acuminatus* and *Cystograptus vesiculosus* Zones include mostly coniform taxa (*Dapsilodus*, *Decoriconus*) which cross the systemic boundary at other localities. A poor single element assigned tentatively to *Oulodus*? *kentuckyensis*, which elsewhere is known only from Silurian strata, was found in the *P. acuminatus* Zone.

These results suggest that more attention should be made to recover conodonts from shales, particularly in graptolitic shale sequences. The above data must be used with caution until more material is discovered. However, the situation is perhaps analogous to the presence of poorly preserved, rare graptolites within the conodont-rich Anticosti Island carbonate boundary sequence (McCracken & Barnes 1981; Riva, this volume). It remains one of the future challenges to find a boundary sequence that yields both well preserved and abundant, biostratigraphically diagnostic conodonts and graptolites across the systemic boundary.

Acknowledgements

Ms Felicity H. C. O'Brien provided invaluable research assistance aspects and C.R.B. acknowledges financial support from the Natural Sciences and Engineering Research Council of Canada.

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